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ABSTRACT

In a speech presented at the Annual Meeting of the American Speech and Hearing Association (1974), the author discusses prospective direction for research in speech recognition and comprehension of the hearing impaired. A theoretical perspective focuses on the role of probabilities in the process of transmitting and receiving auditory messages. Research needs noted include the importance of investigating clients' information processing, of finding effective and economical hearing aid fitting procedures, and of developing computer programs for auditory training. (LS)

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STATE OF THE ART IN REHABILITATIVE AUDIOLOGY: SPEECH INTELLIGIBILITY

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State of the Art in Rehabilitative Audiology: Speech Intellibigility
Invited Presentation, Convention of the American Speech and Hearing Association, Las Vegas, 1974

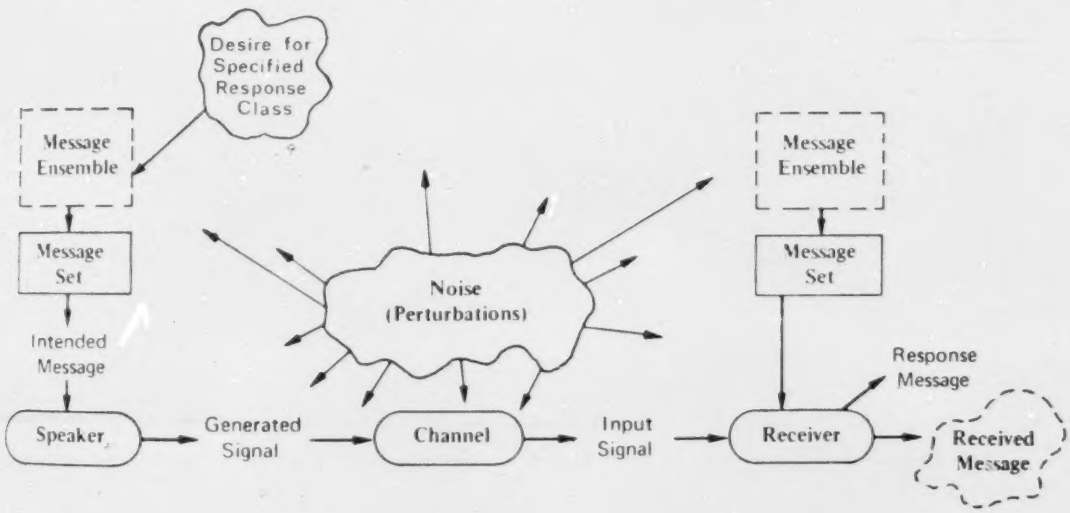
Martin C. Schultz

My remarks today deal with prospective directions for research in speech recognition and comprehension of the hearing impaired. Some of these suggestions come from surveying and critiquing current research trends, others arise out of one or another kind of model about how the hearing impaired client hears speech, and may not reflect an extrapolation from studies presently known to be under way. My suggestions are not necessarily mutually consistent nor supportive of the thoughts of our two learned colleagues. They are offered in a spirit of energizing discussion and mutual sharing of ways to attack these difficult human problems.

Let me begin with a theoretical perspective.

As we are all aware, Shannon presented us with a system for quantifying the uncertainty of messages so that we could apply the mathematics of probability to ongoing signals, as they were transmitted and received. This approach gave rise to much research about Markov processes in signal generation and got us involved in questions like, If I know the first three words, can I guess the fourth? or, How much assistance do I get in synthesizing a total signal when I receive parts of it with reasonable clarity but not other parts? And, as we are also all aware, the research didn't give us anything like the insight or productivity we had early expected so that by the time Chomsky-type rule systems put a stranglehold on probabilistic approaches to speech, they may have strangled what was already a corpse.

But my point is that we considered Shannon's work and applied it in much the same ways as he did. Those particular applications were to prove quite successful



SLIDE 1

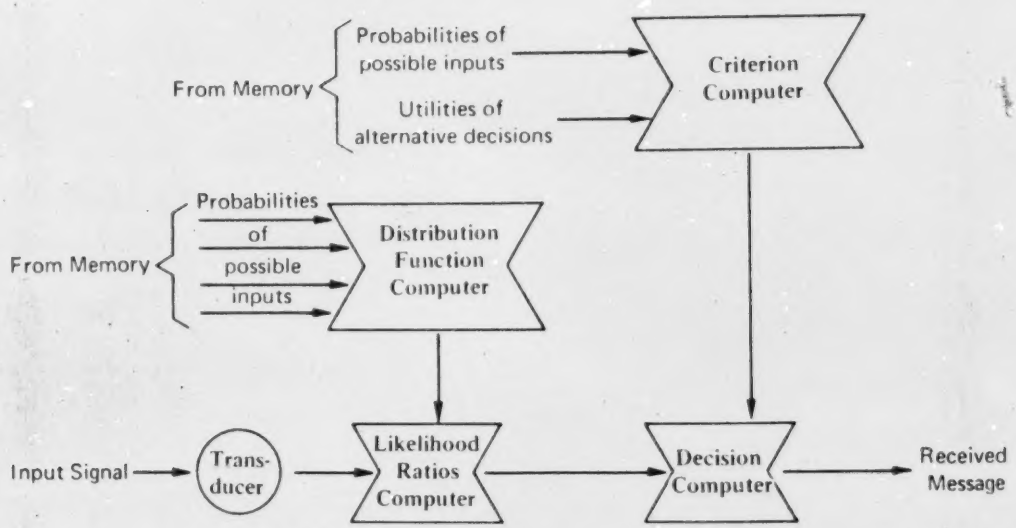


FIGURE 2 *The communication receiver (after Tanner).*

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to the communications engineer but they were not and are not the application we need.

If we stop to consider where probabilities are important to us, I think they are useful in two places. The first is in the choice of message by the talker.

SLIDE I, PLEASE

This is an expanded Shannon model and let me point out the areas of expansion. First, the motivation for the communication is the desire on the part of the talker to energize some particular response from the listener. He has available to himself an infinity of messages he can choose but, somehow the desired response serves as a filter to extract only that set of messages that have a probability greater than zero of motivating the desired response. At the other end of the slide, we have a listener, who is much like the talker in that he can receive and understand almost an infinity of messages, but in this situation from that talker and whatever he perceives as the talker's motives, there is only a finite set of messages he is prepared to receive. The talker settles on a single message that, presumably, maximizes the probability of engendering the attitude or motivating the behavior the talker desires. The hearing impaired listener has to get that message, however it is encoded, so understanding message choice behavior, rather than the area of message encoding is of importance to us. The other locus of importance for probability applications is in the signal reception and interpretation task of the listener.

SLIDE 2, PLEASE

Clearly the listener can use his knowledge of all components of the communication in trying to receive and interpret the signal successfully. By saying all components what I convey in a formal sense is that he processes three kinds of information from memory: he must deal with parameters of possible signals,

the probabilities of these signals as interpreted, and the utilities of these interpretations (their values and costs). In an informal sense, the listener can use his knowledge of the language including the particular social dialect being used, the probabilities of sounds and syllables and words, the cues of place, situation, social milieu and so forth toward establishing what the intent of the talker might be. All of these are aspects of signal reception and interpretation to which probabilitistic considerations are properly applied.

SLIDE OFF

Why should we deal with probabilities? Because I think it might be fruitful to consider that the normally hearing individual, on the average, can take advantage of so much redundancy in the signal and situation that seldom has he difficulty interpreting signals reasonably. The hearing impaired person, on the other hand, runs into repeated difficulty, seems to have to rely on progressively less reliable and/or progressively lower probabilities, and, not only is he frequently wrong but it progressively upsets his confidence in his own abilities and he establishes a system of self-fulfilling prophesies about failure. In other words, the hearing impaired individual develops different probabilities than does the normal and fixes different values and costs to his decisions and there are two implications from that. First, in any research we do on the normally hearing with the idea that we can extrapolate to the hearing impaired, we must be very careful that these differences in probabilities and in payoffs will not be significantly involved. When such differences exist, the extrapolation clearly is at risk. The second implication is that we really don't know very much about how individual hearing impaired people hear speech so let me pursue that for a minute.

When we view hearing rehabilitation as occurring at the periphery. when we view the ear as a mechanical-acoustical instrument, when we view the hearing

aid as an electroacoustical instrument, we are emphasizing the physical world. We are looking at the signal and the distortions imposed upon it. For some selected purposes that orientation may be adequate. But there is major work to be done in the framework of the human being as information processor who brings much more than a distorted signal reception system to his task. He has linguistic, social and speaker-oriented expectations, he has cues at the phonetic level, the syllable level, the phrase level etc. with which he tackles interpretation of the distorted signal. Some of these cues are of assistance, some of them are no longer operative, and we must presume that some are now systematically misleading and therefore probably very highly disruptive. Running monosyllabic word tests or even isolated sentence tests will not give insight into many of the client's information processing and social processing problems. When you do that kind of extrapolating without taking those different probabilities and utilities into account, operationally you have decided they have no importance to you though they may be more important for understanding the client than anything you actually test about his communication. That's one focus for research, let's go on to another.

One needed research azimuth deals with the client's trustworthiness in hearing aid quality judgments. The problem arises in finding effective and economical hearing aid fitting procedures. Such procedures must balance the current desires of the client for what he thinks he remembers clarity to be like, in the framework of the acoustical characteristics of the combination of low fidelity instrument and low fidelity ear, against his long run needs for effective speech cue information. It seems unclear that the client is the best immediate judge of what aid will, in the long run, give him best performance. If we could get him interacting with a computer, then the most effective hearing aid selection might turn out to be strongly influenced by

a plotting of the learning curves he would generate in discrimination and recognition tasks which included trial-by-trial machine feedback. It seems intuitively that an aid yielding steeper slopes holds more promise, whether the patient is immediately more satisfied with the sound familiarity of that aid or not.

Associated with this last question, if one believes in some kind of "wired-in" theory of speech recognition, then a major area of investigation, barely tapped with the hearing impaired population, involves the question of how much plasticity has the hearing impaired individual or indeed even the normal for learning new cues, for erasing useless or confusing cues? What kind of adjustment time does he require for changing cue systems, if he can do that, and how can we help him in this task? The question of cue plasticity, or one's ability to alter response strategies, is an area for future work. It is obvious that much of this work can be done with the normally hearing but a great deal of it will require hearing impaired subjects. I would add one caution before moving to another direction for research.

If there is a special portion of the nervous system that processes speech and if it is true that that processing differs from processing of non-speech signals, then the experiments examining plasticity of the speech recognition system had better restrict themselves to the use of speech as the signals in the experiments. And I would remind you that if we are forced to conclude that the hearing impaired subject has only very limited plasticity -- that somehow he is constrained to follow the lead of whatever cues he does get, misleading or not, ambiguating or not, then auditory rehabilitation will have to take on a much more synthetically-oriented rather than analytically-oriented character. We will, in this case, have to do the research to learn how to train our client to assume postures and poses that will cause the talker to speak

louder or articulate more precisely. We will have to do the experimental work to learn how to train our client to manipulate a variety of non-verbal communication configurations. Equally important, we will have to help him enhance the sensitivity of his expectations on the talker.

Another topic. How does one write the equation between auditory and visual input for the hearing impaired? We know that, except under difficult circumstances, the normally hearing person doesn't have to see the talker at all. As his auditory system experiences progressively more difficulty, his visual system makes a progressively larger contribution. But should we automatically take the view that the auditory system alone is to be maximized in hearing aid fitting? Is it appropriate without specifically researching the question, to accept the orientation that a hearing aid is to maximize speech recognition in the auditory domain? Should one even care which modality contributed what portion of the aided plus visual speech intelligence score? Perhaps a hearing aid most emphasizing cues that unambiguate the lip-reading contribution would be worth thinking about. I would remind you that one cost of selecting hearing aids based strictly on the combination score would be that we would lose the control on speaker variance now coming from standardized recorded tests. But an aging population and the likelihood that progressively more often hearing aids will be purchased by third parties requires a re-examination of the argument.

For those of you who might not have read the very powerful review article on tactile displays of speech by Kirman in Psych. Bull for 1973, I would say that it may be time to rethink the potential contribution of the tactile sensory system to the processing of auditory information -- partially speech recognition, but also binaural signal selection and background squelch, perhaps vocal pitch information, perhaps speech timing information and so forth.

In this day of large scale, time-shared computers, I would like to see some materials developed that would be programmable for auditory training so that a client could simply sit down at a console, call for a program or programs that would force him to work on discrimination in a mode that would give him feedback trial by trial, at his own pace, without occupying a clinician. The computer could also give the clinician the learning curve of the client so that decisions could be forthcoming about when to shift materials, or to shift rehabilitation focus, etc. The computer could as easily deliver a short passage and inquire about topic area, or what emotion was being expressed or whatever. That is to say, it could as easily work on a synthetic approach as on an analytic. But we need such programs.

You might consider further that, when your client is seated in front of the computer terminal, his earphones should be wired out-of-phase so as to maximize the contribution that the asymmetry of the waveform makes to his understanding.

Let me go back to the psycholinguistic position that language is wired-in to the left hemisphere. It seems to me that one implication, worthy of study but also of consideration for your patients right now, in that the ear of choice for a hearing aid should be the right one. We all know that I cannot use this rule unequivocally without some specific research directed to the question but I raise the point even though it has likely struck many of you before. The recent study of Frederiksen and his colleagues in Scandinavian Audiology about the inability of some significant proportion of patients with presbycusic hearing loss to wear binaural amplification raises the same question about which should be the ear of choice for a single aid. The wired-in model suggests that it frequently should be the right ear even when that one seems to be the poorer. How much poorer and whether or not we should revise

the general guidelines we use for making that decision are now reopened as empirical questions.

Here is still another tack for hearing aid appraisal not currently in the literature -- no better but different. I would like to see someone evaluate a two-level strategy where the first level defines reasonable goals for the patient in making the decision that he will opt for an aid or aids or not. I suggest something like a multiple regression on age, magnitude of threshold shift and perhaps its slope, percentage discrimination loss, education, ability to withstand adverse S/N conditions, proximity to binaurality, job and social demands, and perhaps other considerations. All of this is done without an aid. The second part, done with an aid or aids, is a more refined analysis involving aided loss, discrimination or recognition scores with progressively larger multisyllabic units so that coarticulation properties and the subject's expectations can be expected progressively to obscure phoneme discriminability, and ability to withstand adverse S/N ratios with the aid. I think the former portion will set reasonable target values for hearing aid assistance and the finer component will differentiate among aids.

Why don't I stop there so we can get some reactions?